



University of Wisconsin-Madison Space Science and Engineering Center
**Cooperative Institute for
Meteorological Satellite Studies**



Improving very-short-range Forecasts of the Pre-Convective Environment using Operational GOES Satellite Observations

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**Expanding the value of Geostationary Sounding Products
from Observations to Forecasting**

What are we trying to improve?

Short-range forecasts of timing and locations of severe thunderstorms
- especially hard-to-forecast, isolated summer-time convection

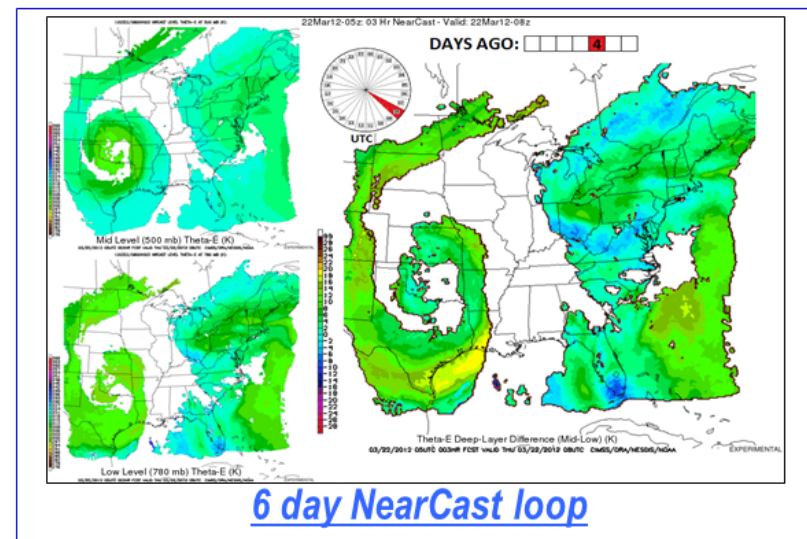
What are we trying to correct?

- *Poor precipitation forecast accuracy in short-range NWP (esp. in summer)*
- *Under-utilization of satellite moisture information over land in NWP*
- *Loss of Infra-Red (IR) satellite observations about the convective environment after convection has begun*

**Why should forecasters be interested in
GOES-based NearCasts ?**

**Because they provide
unprecedented understanding
of the past and future evolution of
multi-level Moisture and Stability fields**

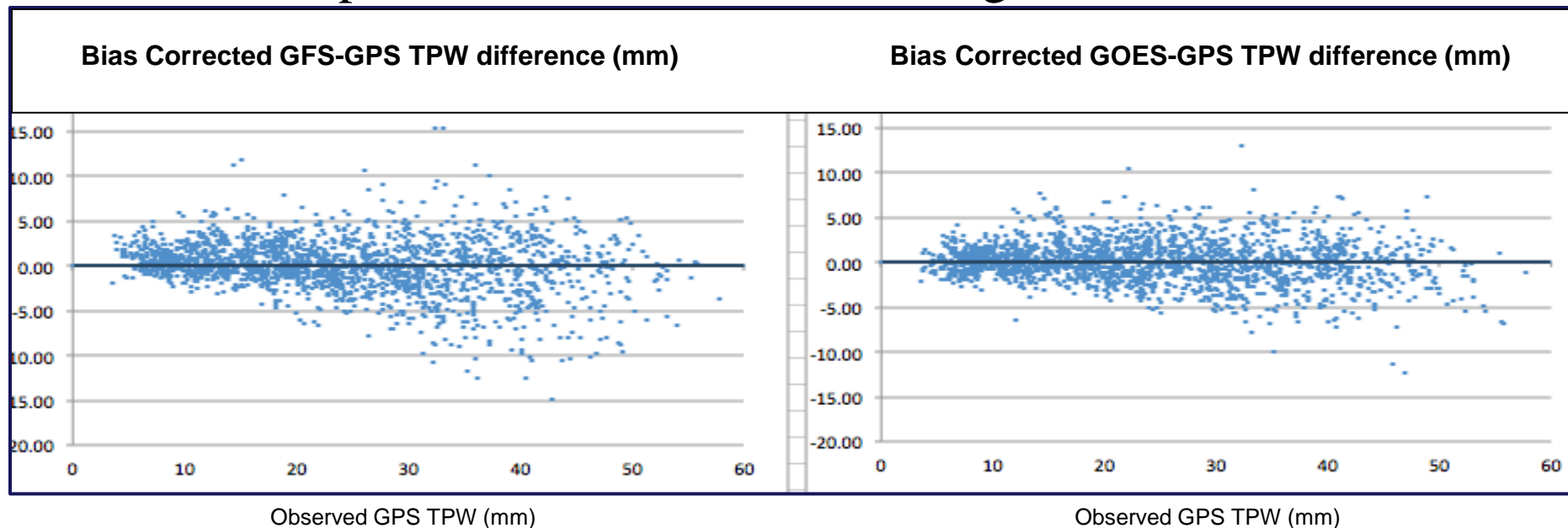
- Parameters that GOES observes well -



Evaluation of GOES Precipitable Water Retrievals

Fundamental Question: How good are GOES Moisture Retrievals?

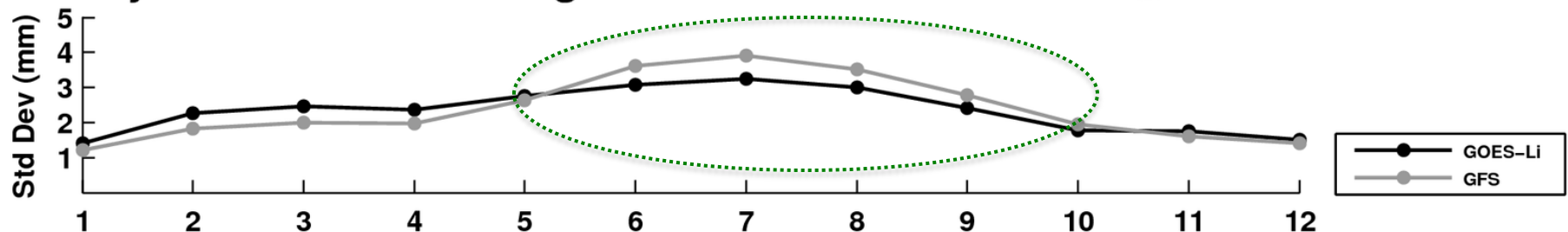
- Comparisons against GPS TPW observations around the US show:
- GOES TPW (Li retrievals) data have a wet bias
 - Worst at time of day when GFS has highest precipitation bias
- GOES TPW improves upon GFS First Guess:
 - Reduce spread of errors at all TPW ranges



Evaluation of GOES Precipitable Water Retrievals (Using NCEP GFS for First Guess)

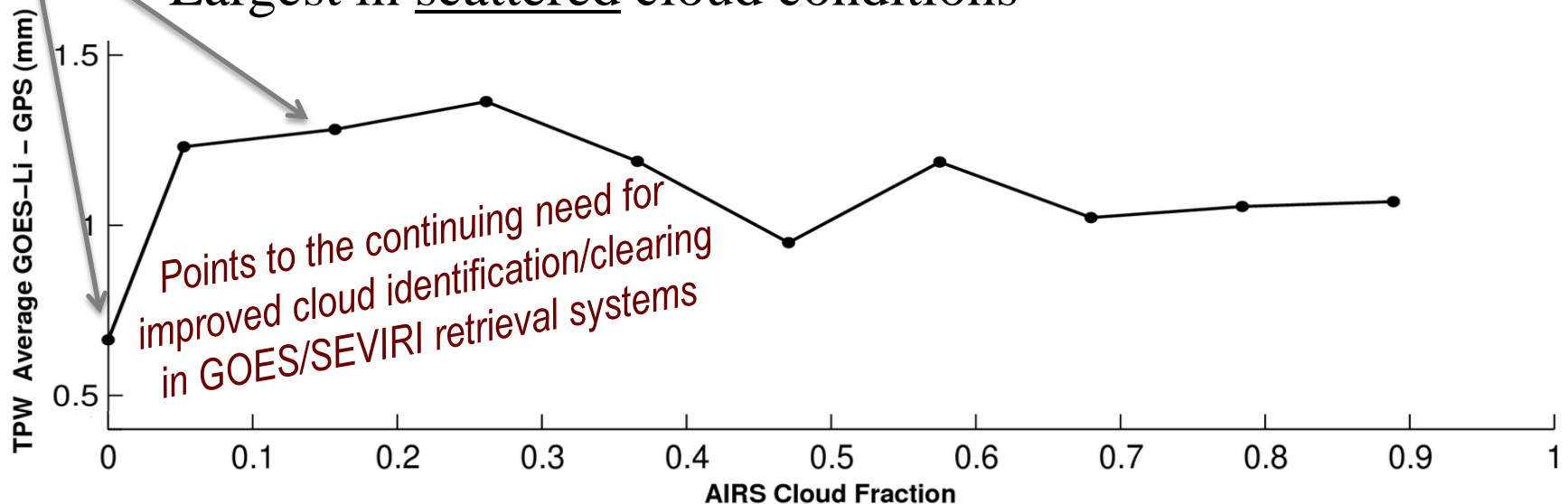
- Comparisons against GPS TPW observations around the US show:
- GOES TPW (Li retrievals) data have a wet bias
 - Worst at time of day when GFS has highest precipitation bias
- GOES TPW data show greatest improvement over GFS First Guess:
 - 1) In warm months (*when NWP precipitation skill is worst*) and
 - 2) Using 06Z, **12Z** and 18Z GFS guess fields

Monthly GOES–Li and Background GFS TPW Initialized @ 12Z v. GPS



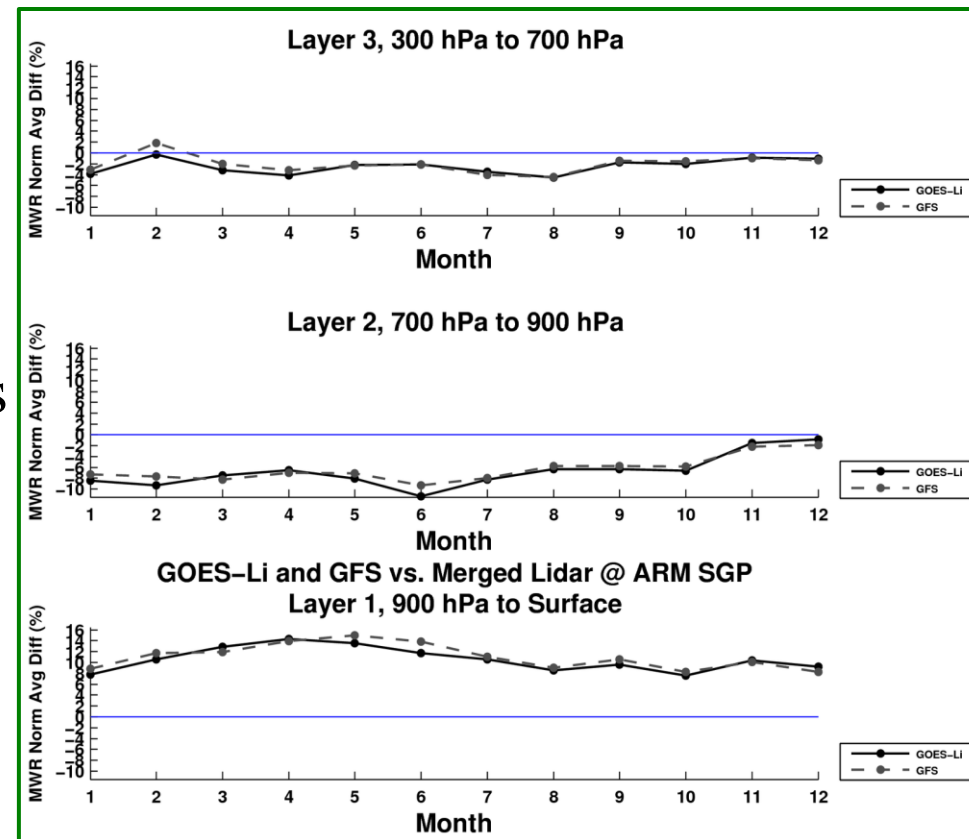
Evaluation of GOES Precipitable Water Retrievals *(Using NCEP GFS for First Guess)*

- Comparisons against GPS TPW observations around the US show:
- GOES TPW (Li retrievals) data have a wet bias
 - Worst at time of day when GFS has highest precipitation bias
- GOES TPW errors are:
 - Smallest when co-located AIRS retrievals shows clear skies
 - Largest in scattered cloud conditions



Evaluation of GOES Precipitable Water Retrievals (Using NCEP GFS for First Guess)

- Biases can be corrected!
- Multi-layer comparisons against Raman Lidar observations from the ARM CART site in Oklahoma show:
 - Distinctly different biases across the 3 PW layers
 - Match GFS very closely
 - Mixing Ratio Biases have:
 - Significant annual cycles
 - Daily cycles vary by GFS cycle time
 - Normalized Biases:
 - Have smaller annual cycle



Normalized GOES TPW Bias
Monthly for 2011

What are we trying to improve with NearCasts?

*Short-range forecasts of timing and locations of severe thunderstorms
- especially hard-to-forecast, isolated summer-time convection*

What are NearCasts?

NearCasts are new, data-driven analyses and 1-9 hour forecasts designed to identify areas where convection will (*or will not*) form

Use what GOES observes best – Upper and Mid-Level Moisture

Use all full-resolution, clear-air GOES observations of moisture and temperature made over land – enhance DPI analyses

These data are not included in operational NWP systems

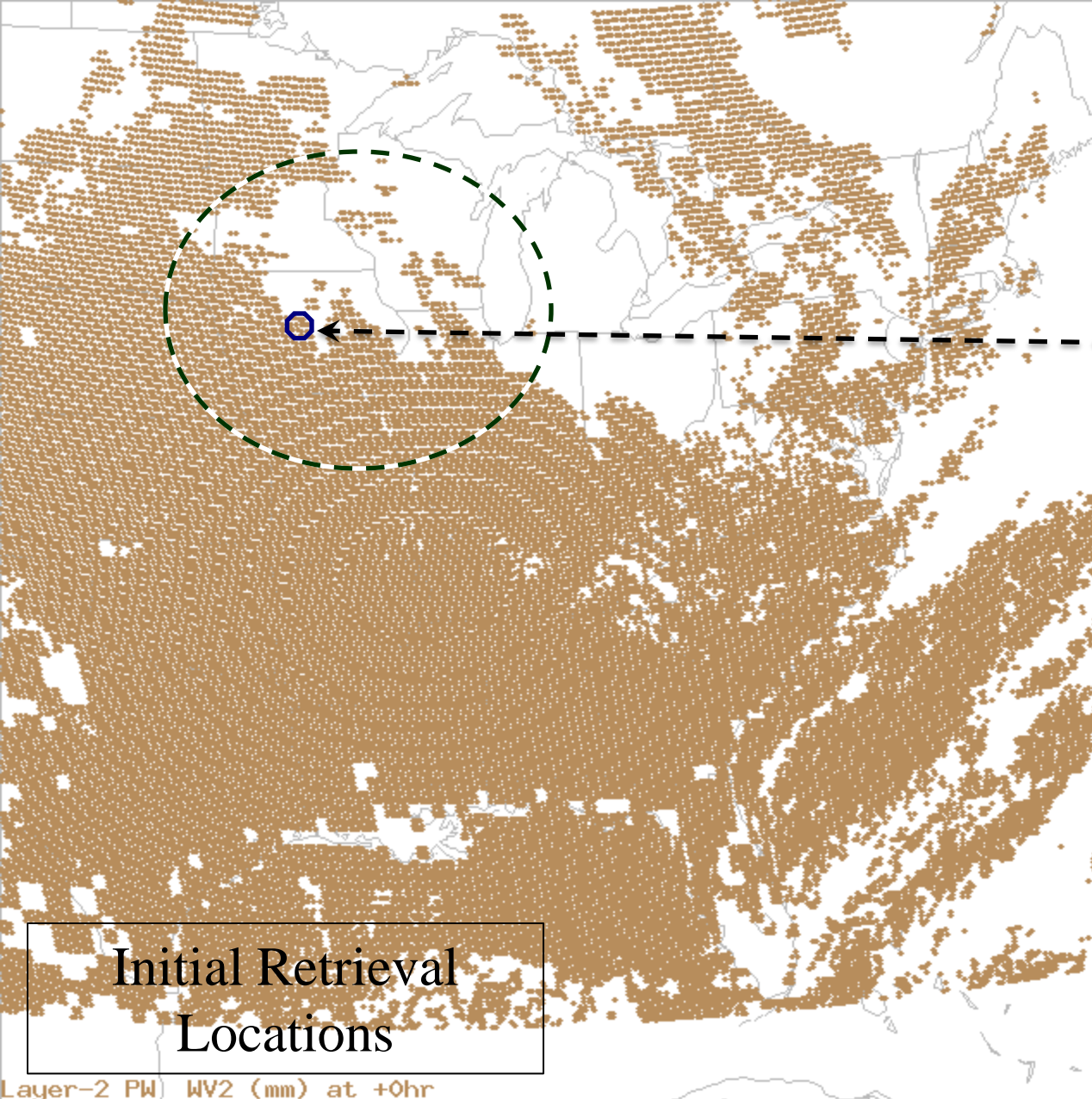
Lagrangian techniques provides forecasters with real-time tools:

- Available within minutes of observation times,*
- Frequently updated (hourly or sub-hourly), and*
- Preserve observations better than traditional NWP products*

Lagrangian NearCast

How it works:

- 1) ***Winds and height gradients from an NWP model are interpolated to full resolution retrieval locations (DPI points) at multiple levels***



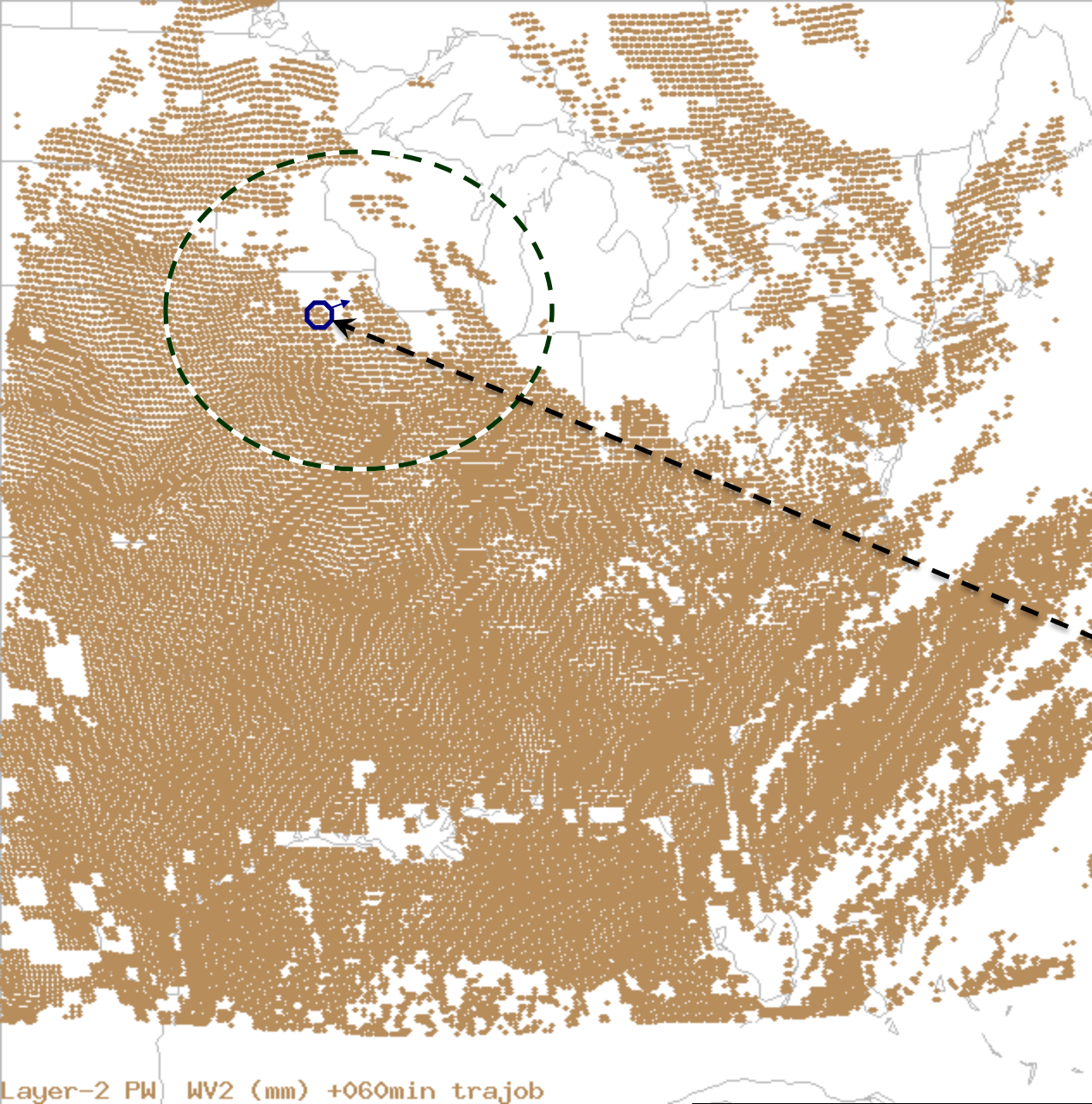
Layer-2 PW WV2 (mm) at +0hr

13 April 2006 – 2100 UTC
900-700 hPa GOES PW
0 Hour Ob Locations

Lagrangian NearCast

How it works:

- 1) Winds and height gradients from an NWP model are interpolated to full resolution retrieval locations (DPI points) at multiple levels
- 2) *Parcels are moved to new locations, using dynamically changing winds using 15 min. steps*

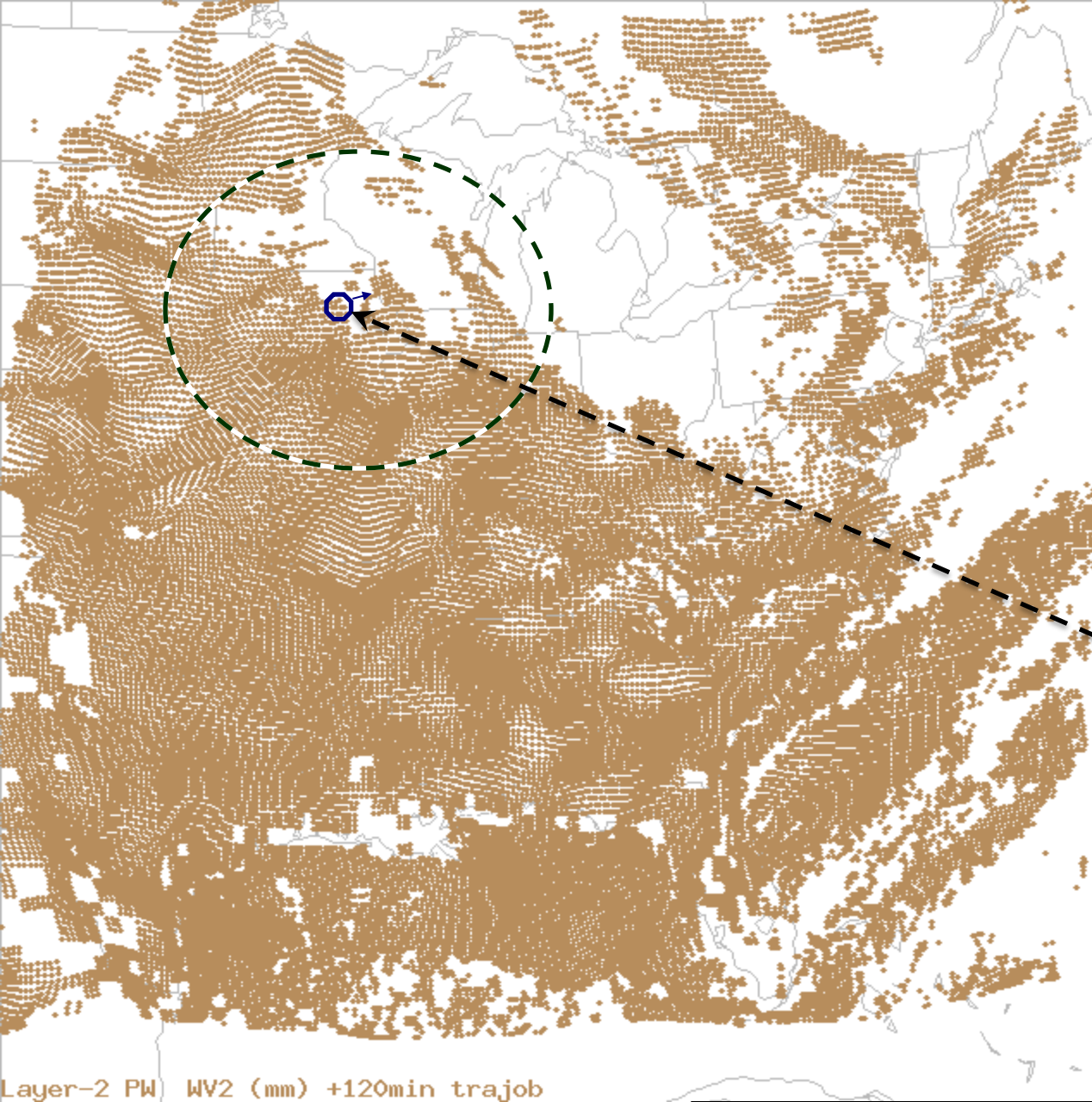


13 April 2006 – 2100 UTC
900-700 hPa GOES PW
1 Hour NearCast Obs

Lagrangian NearCast

How it works:

- 1) Winds and height gradients from an NWP model are interpolated to full resolution retrieval locations (DPI points) at multiple levels
- 2) *Parcels are moved to new locations, using dynamically changing winds using 15 min. steps*

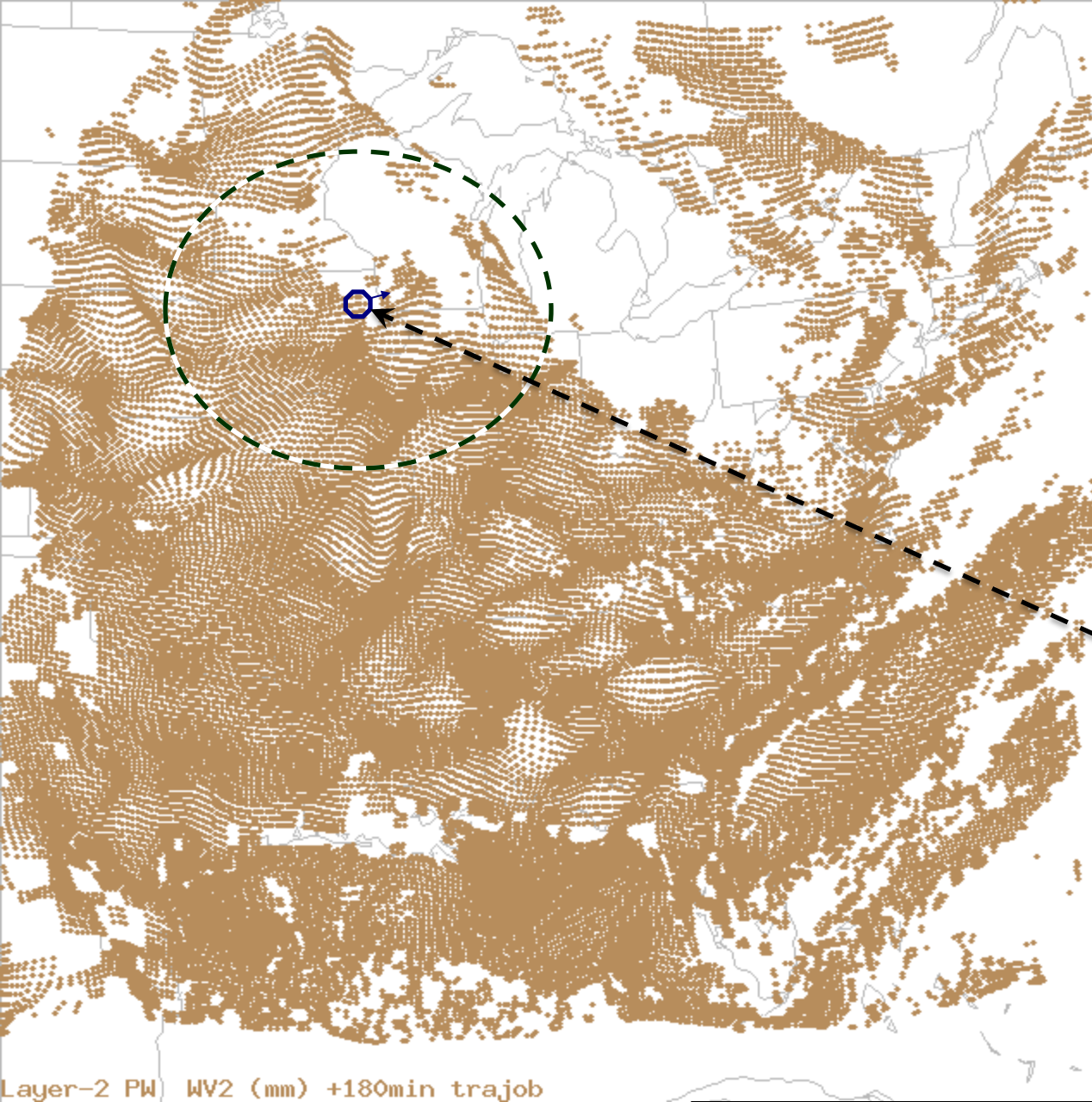


13 April 2006 – 2100 UTC
900-700 hPa GOES PW
2 Hour NearCast Obs

Lagrangian NearCast

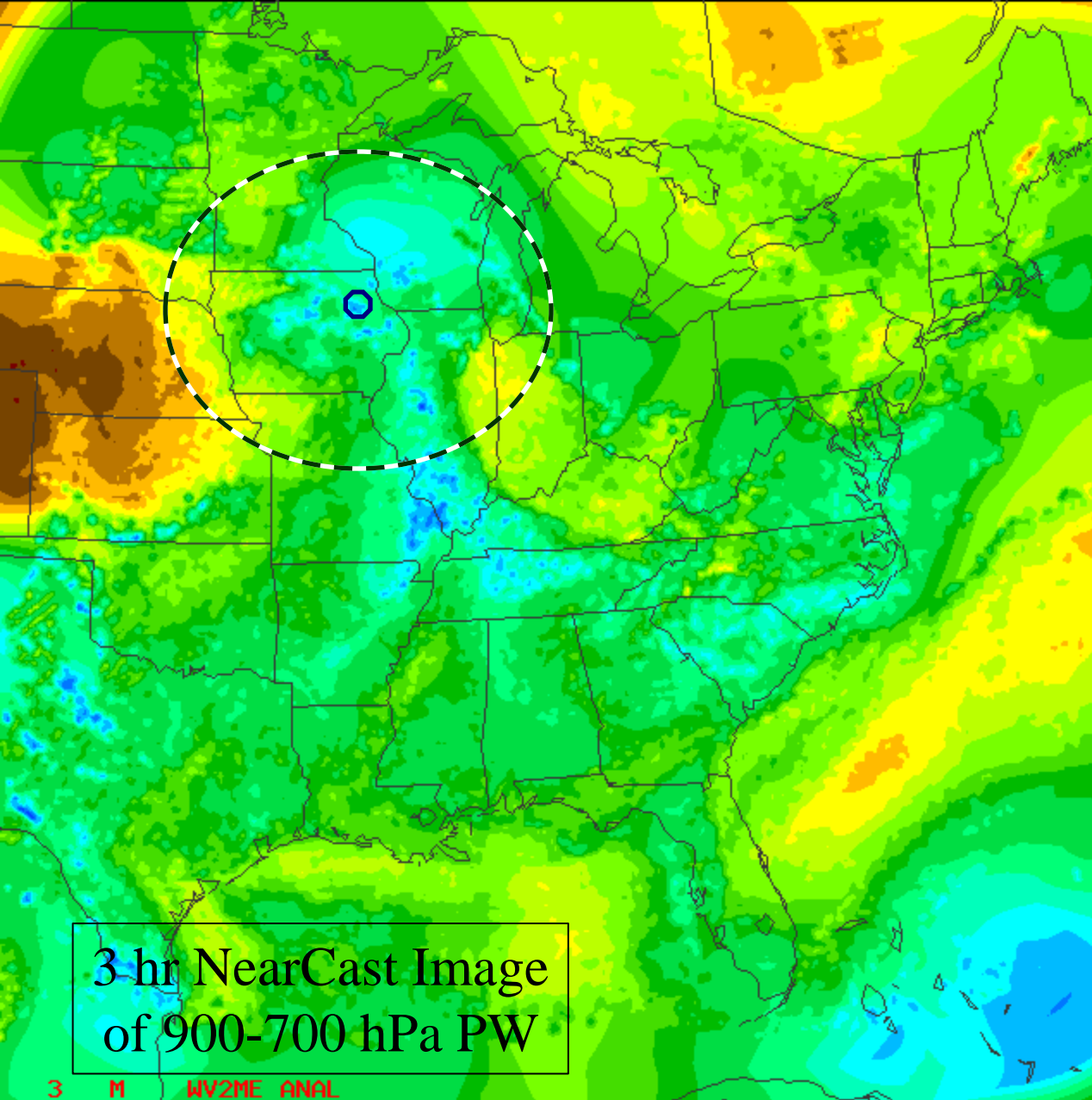
How it works:

- 1) Winds and height gradients from an NWP model are interpolated to full resolution retrieval locations (DPI points) at multiple levels
- 2) *Parcels are moved to new locations, using dynamically changing winds using 15 min. steps*



Layer-2 PW WV2 (mm) +180min trajob

13 April 2006 – 2100 UTC
900-700 hPa GOES PW
3 Hour NearCast Obs



CIMSS

mm
Dry



Moist

Lagrangian NearCast

How it works:

- 1) Winds and height gradients from an NWP model are interpolated to full resolution retrieval locations (DPI points) at multiple levels
- 2) Parcels are moved to new locations, using dynamically changing winds using 15 min. steps
- 3) The full set of “moved” moisture observations are then are combined with past NearCasts for the same time to produce an “Forecast DPI” display

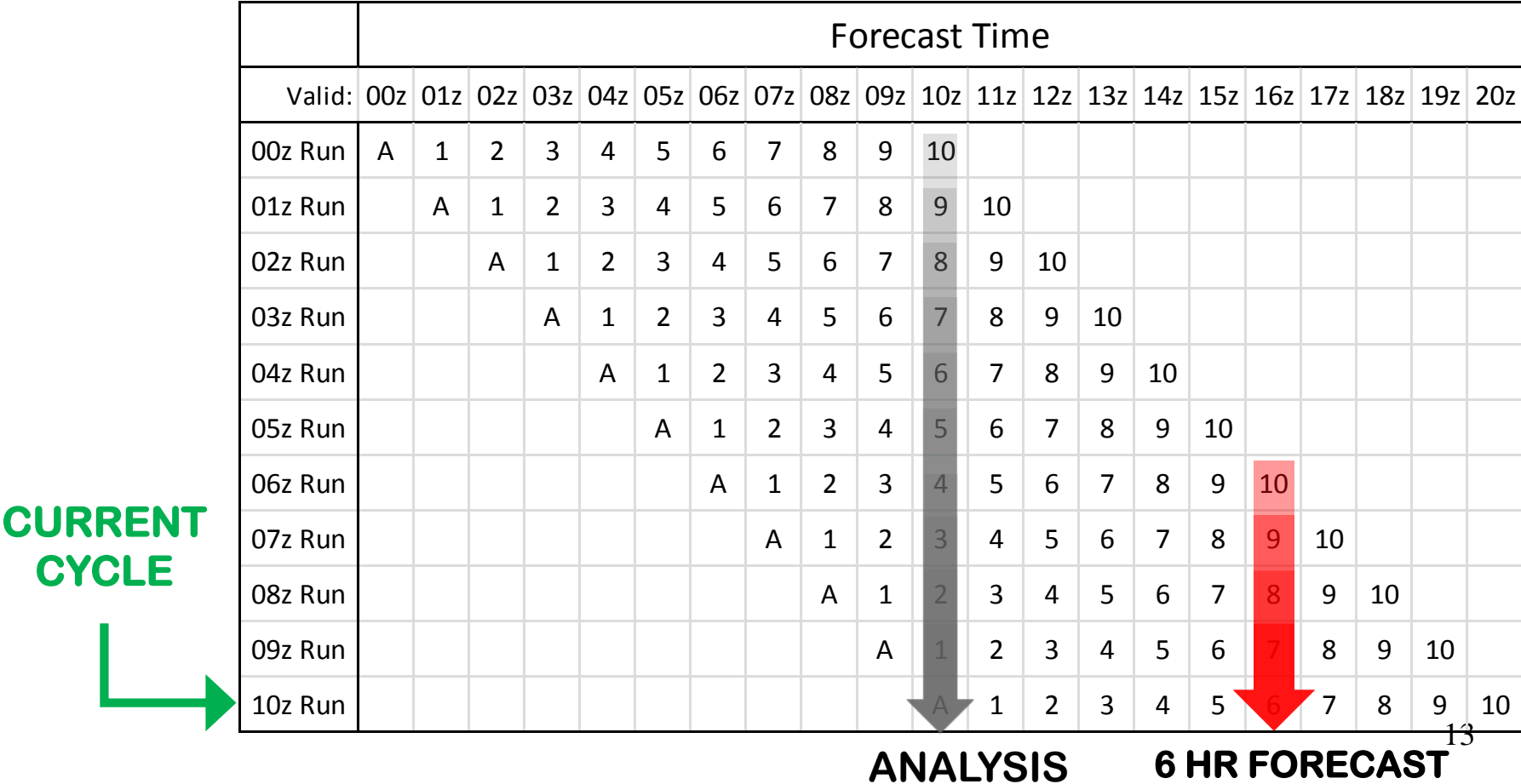
3 hr NearCast Image
of 900-700 hPa PW

10 km data, 10 minute time steps

13 April 2006 – 2100 UTC
900-700 hPa GOES PW
3 Hour NearCast Image

A Data-Driven System that Preserves Previous Observations

NearCasts analyses and forecasts retain up to 10 hours of observations in its products by using projections of data from previous model runs to produce hourly updated displays.



Examples over the past several years have confirmed:

- *The melding of data projected forward in space from the past 10 GOES observation cycles in the NearCast analyses substantially improves data coverage when compared with traditional DPIs*
- *The use of Equivalent Potential Temperature (θ_e - combining both thermal and moist energy) as the primary NearCast analysis and forecast parameter is beneficial both for :*
 - 1) Monitoring lower-level moisture sources and*
 - 2) Defining Convective Destabilization more completely*

*NearCasts are useful in defining
where and when convection will and will not occur*

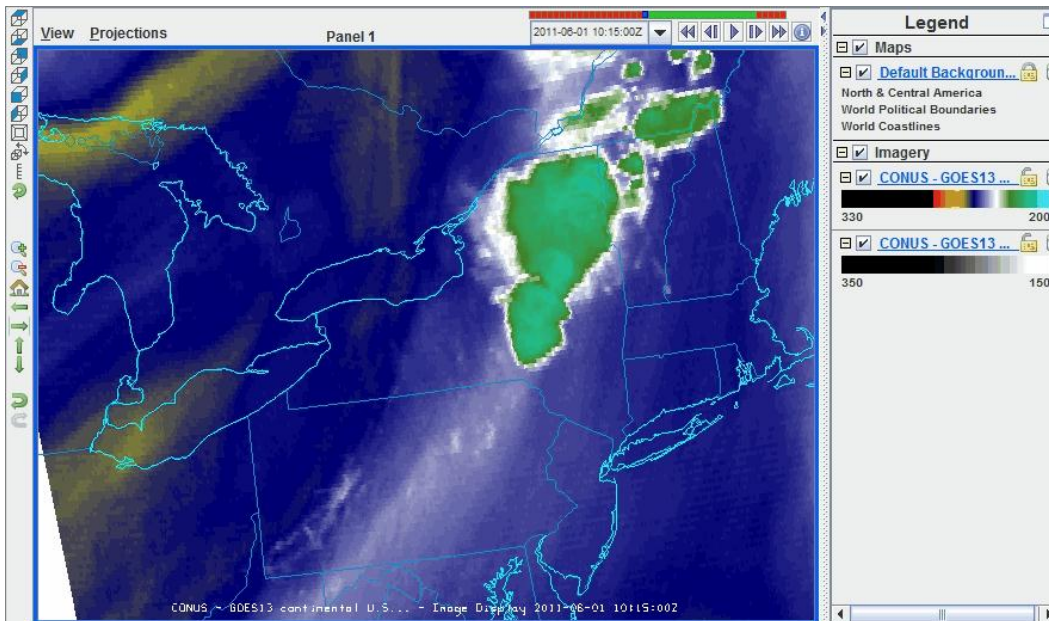
How are the Satellite Observations Used to Gauge Atmospheric Stability?

- **Equivalent Potential Temperature (Theta-e)** contains information about the temperature and moisture content of air.

- In the NearCast model- Theta-e Difference:

$$\theta_e^{500mb} - \theta_e^{780mb} > 0, \text{ convectively stable}$$

$$\theta_e^{500mb} - \theta_e^{780mb} < 0, \text{ convectively unstable}$$

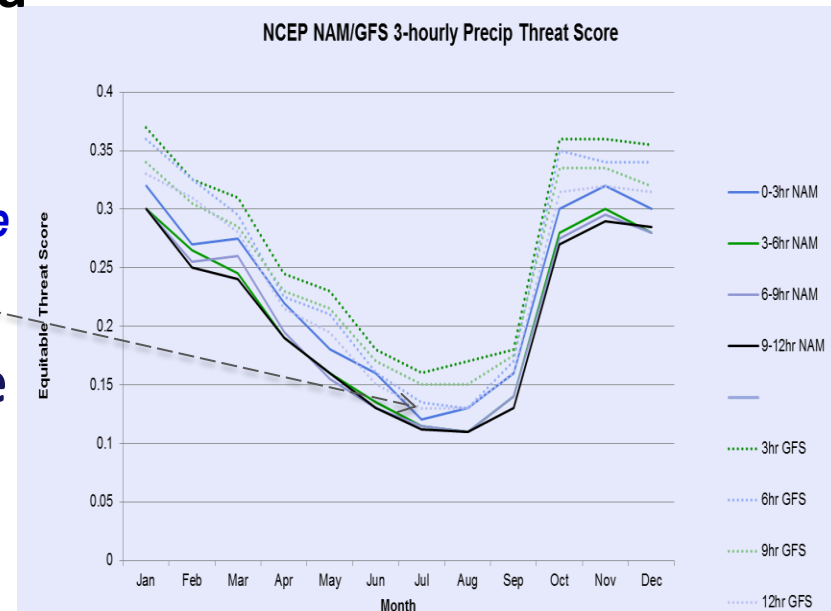


Water Vapor Imagery: Warm=dry, Cool=wet

- **Convective Instability** provides an objective means of identifying where very dry air at the upper levels is overtaking moist air at the low levels - a classic location for storm development observed in satellite imagery.

2011 NearCasting PG evaluations comments included:

1. Provide information about dynamic triggering (*Later*)
2. Extend forecast length (*Increased from 6 to 9 hours*)
3. Clouds limit the usefulness of product at times (*Extended analysis cycling using past data has helped*)
4. Nearcast fields (especially tendencies) were most useful when used to diagnose initial growth and coverage
5. Nearcasts most valuable when used in conjunction with observations and other model data (both where convection **will** and **will not** occur)
 - Useful in updating/verifying NWP guidance
 - Note: NWP correct only ~15% in summer
6. Forecasters need more experience using new products and help interpreting the observed fields & combined NearCast parameters



2012 NearCasting PG evaluations comments included:

1. Forecasters were accepting the difference field as a new prediction tool for severe convection! ***Enhanced training has helped forecasters understand the importance of upper-level dryness and lower-level moisture - parameters that GOES observes well***
2. Need more information about dynamic triggering (*Isentropic version provides this, as well as information on shear and other stability parameters*)
3. Clouds can limit the usefulness of product at times (*Due now to fewer retrievals using improved “Li” retrieval system, which removes more cloud-contaminated observations*)
4. Nearcast fields (especially tendencies) were most helpful when used to compliment NWP & diagnose initial growth and coverage
5. Improved Education and Training material helped forecasters:
 - *Understand* how to use the new products,
 - *Interpreting* the NearCast analyses and forecasts and
 - *Absorb* the content of the combined-parameter displays

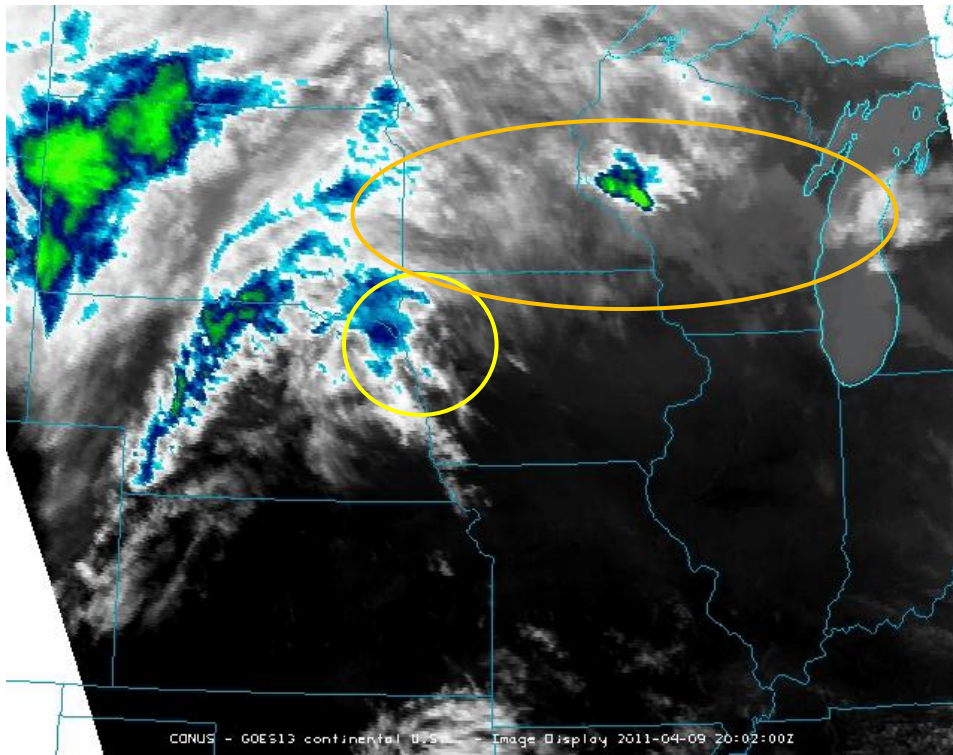
‘New’ users need to be ‘exposed’ to these new products

A new Case Study

April 9, 2011 – Mapleton, IA (western Iowa)

- **Isolated Tornado struck Mapleton around 00z,**
- **Convection starts in far eastern Nebraska about 2230z just as area became substantially more unstable**
- **Note that Upper-Level dry air moves over same area precisely at time of convection initiation**
 - **Already obvious in 17z runs and enhanced later**
- **Heavy Precip later in day over SE Minnesota**
 - **Isolated in Isentropic version**
- **Also note the activity through North and South Carolina with very large hail.**
 - **This is associated with a push of high Lower-Level Theta-E and instability into a previously stable area.**

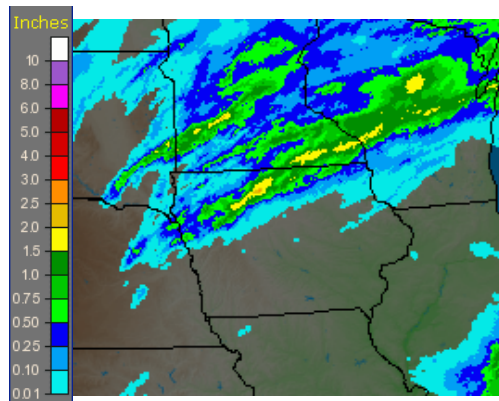
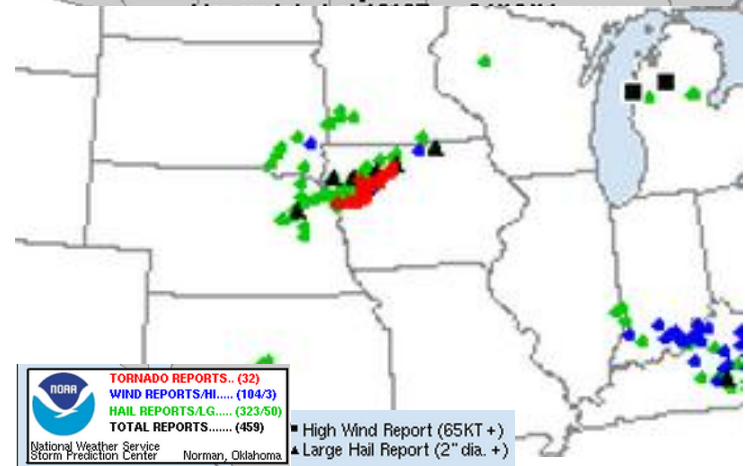
April 09, 2011-Two Types of Convection



- **Initial severe convection** rapidly developed in E Nebraska around 22z and moved through NW Iowa before dissipating quickly in NC Iowa.

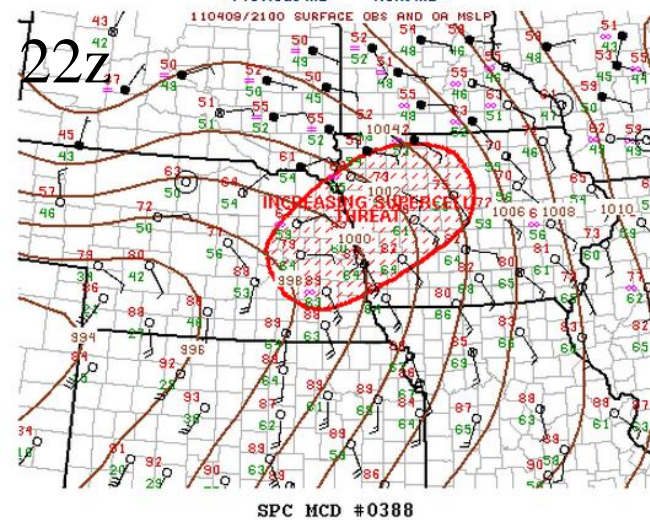
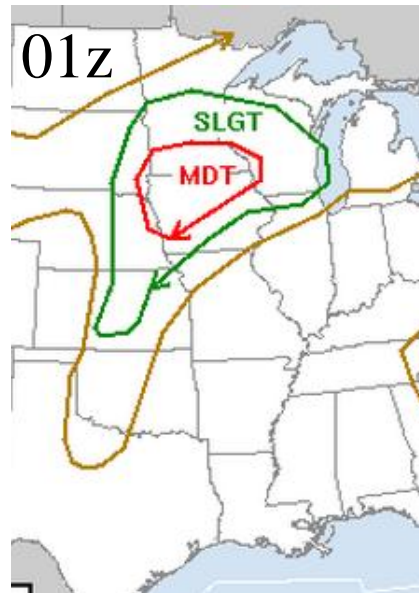
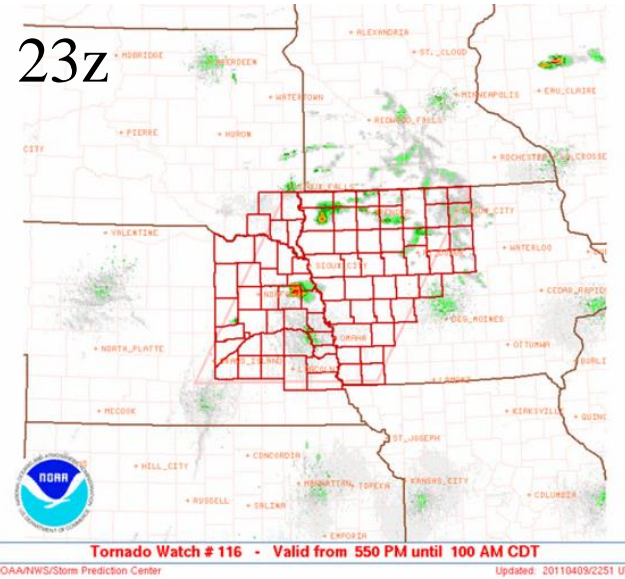
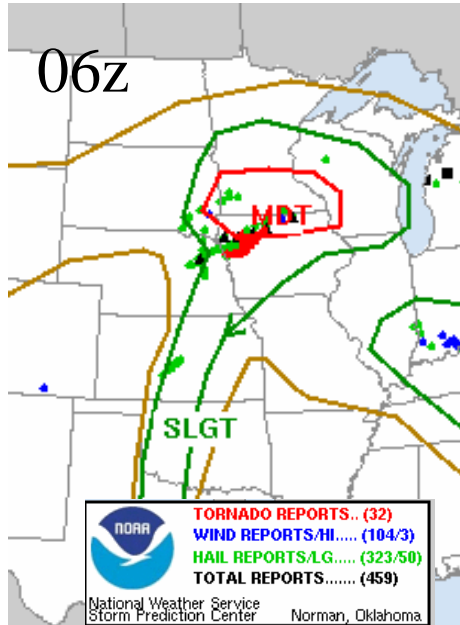


SPC Storm Reports for 04/09/11



- Second round of non-severe convection developed in southern Minnesota around 02z and moved through central Wisconsin producing **widespread heavy rainfall**.

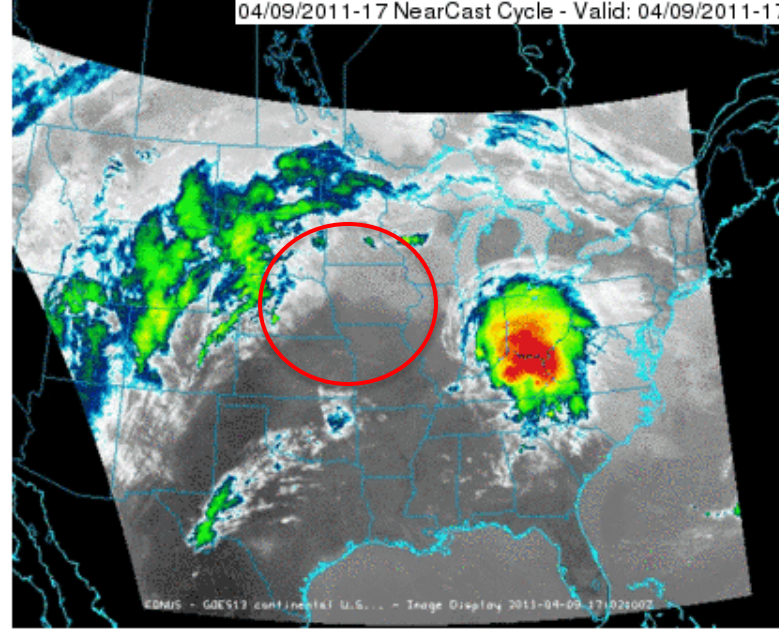
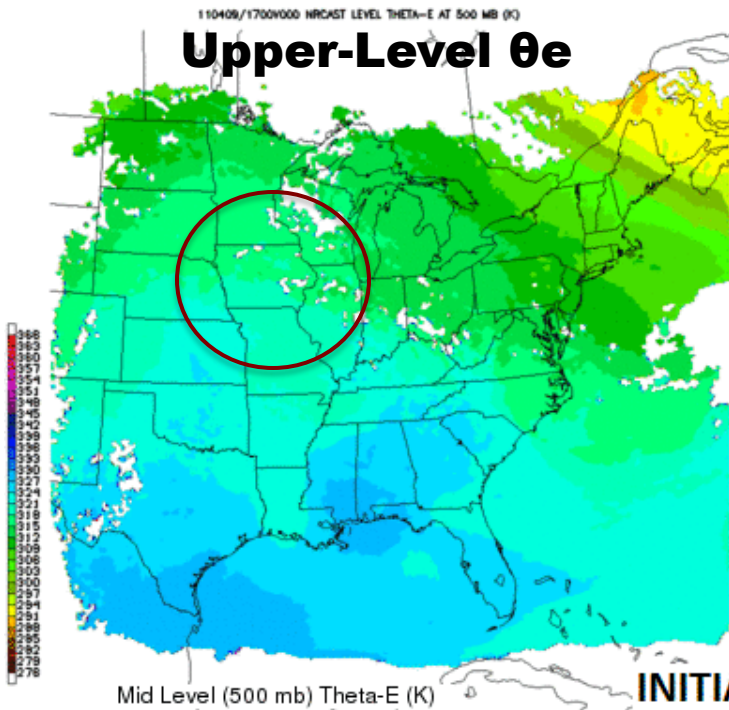
April 09, 2011 Outlooks



MESOSCALE DISCUSSION 0388
 NWS STORM PREDICTION CENTER NORMAN OK
 0505 PM CDT SAT APR 09 2011

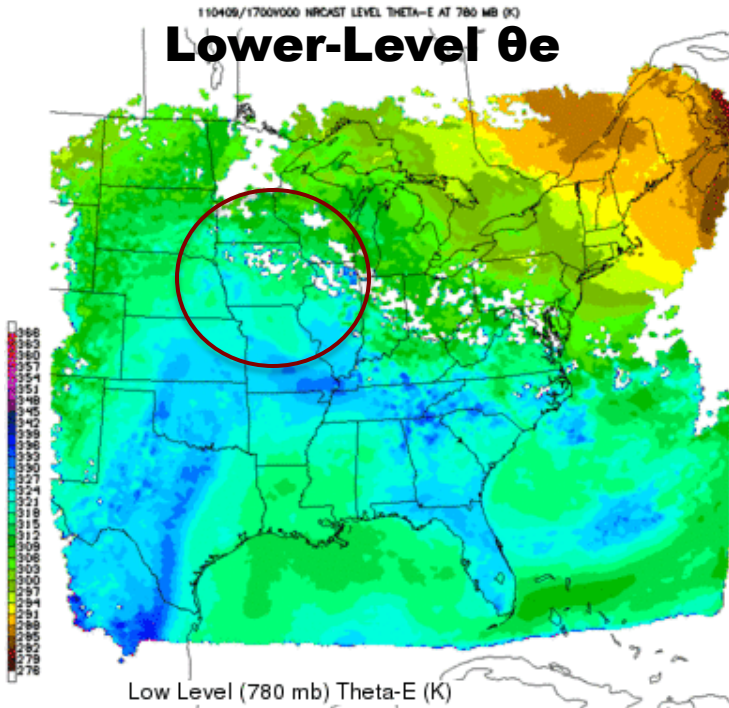
April 9, 2011 – Mapleton, IA (western Iowa)

Upper-Level θ_e

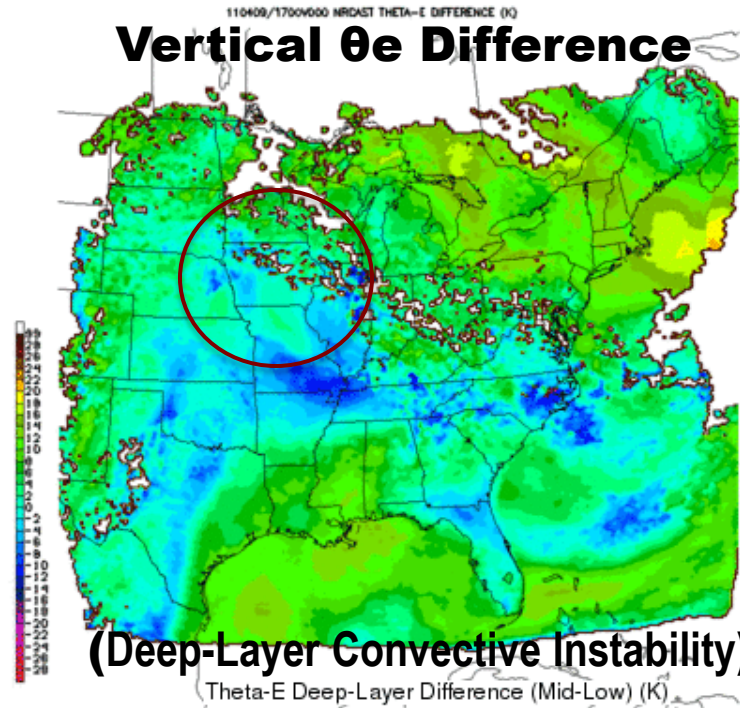


INITIALIZED: 17 z | VALID: 17 | | | | | | | | z

Lower-Level θ_e



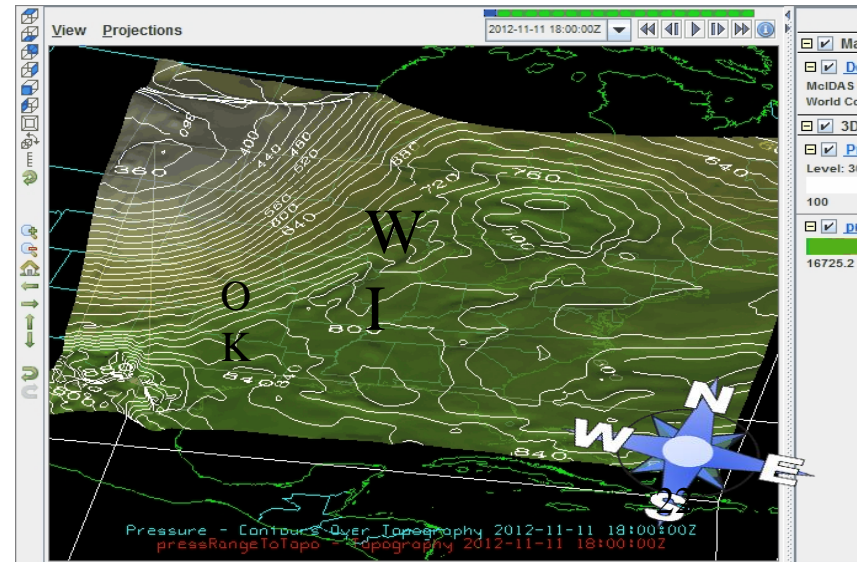
Vertical θ_e Difference



NearCast Images are available <10 minutes after observations on real-time NearCasting web site

Advantages of Isentropic Coordinates

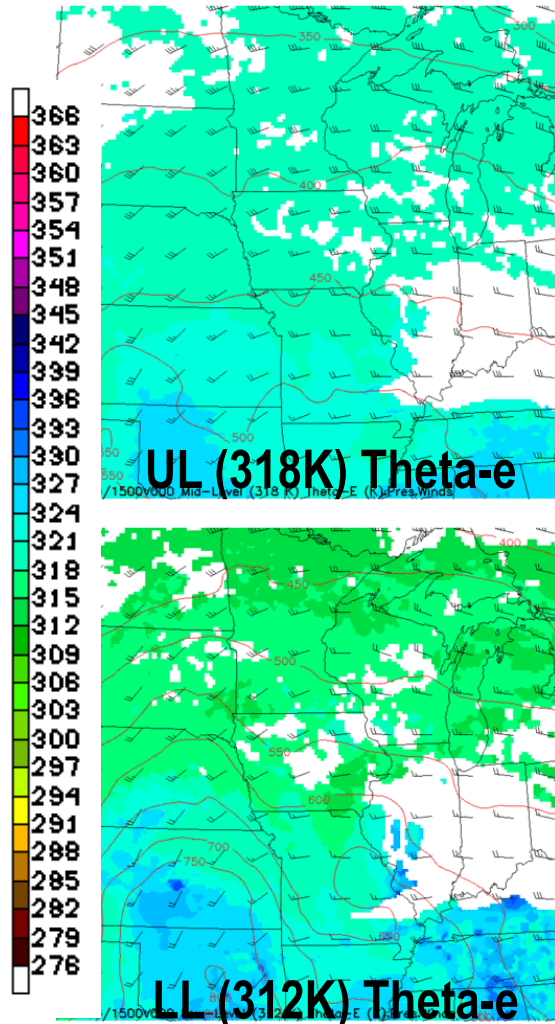
- GOES soundings are only made in **cloud-free** region of the free atmosphere where latent heating is negligible and the **flow is therefore adiabatic**.
- Isentropic surfaces act as **material surfaces** on synoptic spatial and time scales in the absence of diabatic processes.
- The horizontal component of flow implicitly includes the adiabatic component of **vertical motion**, since sloping isentropic surfaces vary in pressure and height
- **Moisture patterns** and flow are more coherent in space and time, since horizontal moisture transport on isentropic surfaces includes the vertical advection component (Oliver and Oliver, 1951).
- Vertical separation between isentropic levels gives a measure of **static stability**, which can be combined with mixing ratio to determine the **total moisture** in a layer (Moore, 1987)



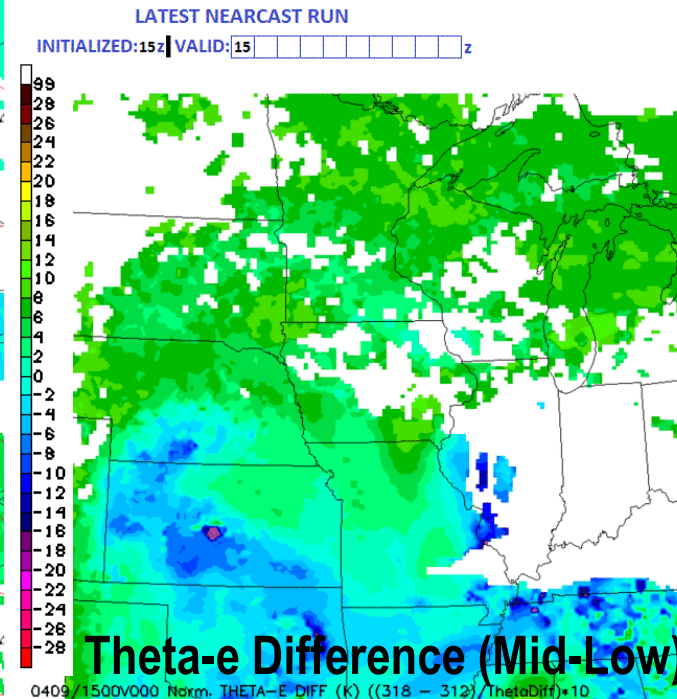
15z Isentropic Nearcasting Model Cycle

Theta-e Products for Severe Weather Outbreak

➤ Upper-level dry air boundary more distinct



20110409-1500z NearCast - Valid: 20110409-1500z



Contours indicate areas of stability change

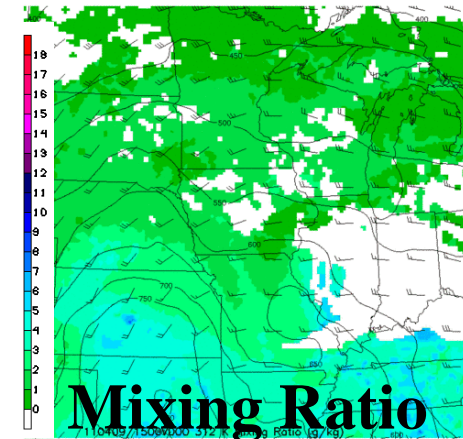
- Convective instability max with strong destabilization tendencies,
- Strong lower-level lifting, and
- Rapid development of veering wind profile at time/location of convection

➤ Low-level theta-e max more well defined from source region

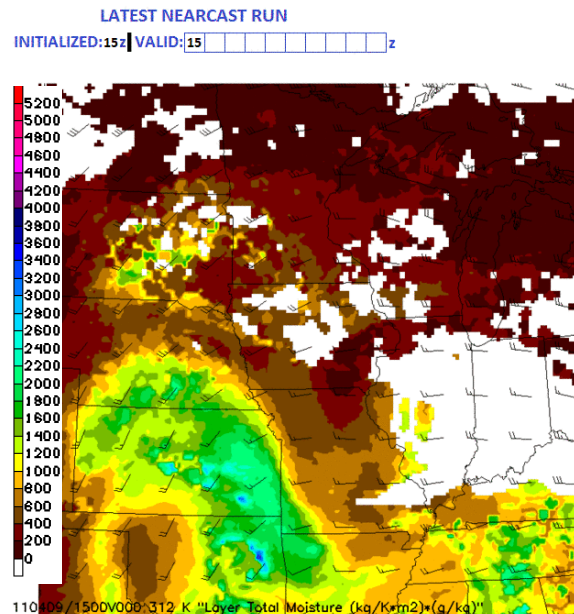
15z Isentropic Nearcasting Model Cycle

Total Moisture Availability Products for Heavy Precip.

Low (312K) Isentropic Level

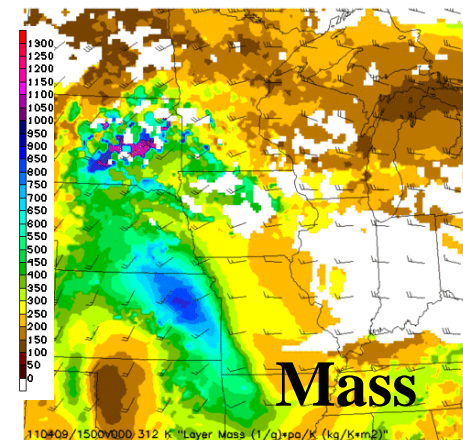


20110409-1500z NearCast - Valid: 20110409-1500z



$\frac{1}{g} \frac{\partial P}{\partial \theta}$: Mass in Isentropic Layer
(Pa/K)

$\frac{1}{g} \frac{\partial P}{\partial \theta} q_{av}$: Total Moisture in
Isentropic Layer
(Pa/K)*MR



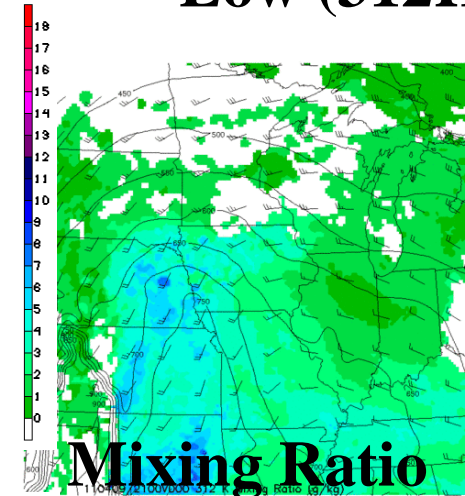
➤ *Highest total moisture was moving east of area of weakest convective instability and was directed towards area of heavy precipitation*

❖ This also allows us to compute the **total moisture flux convergence**

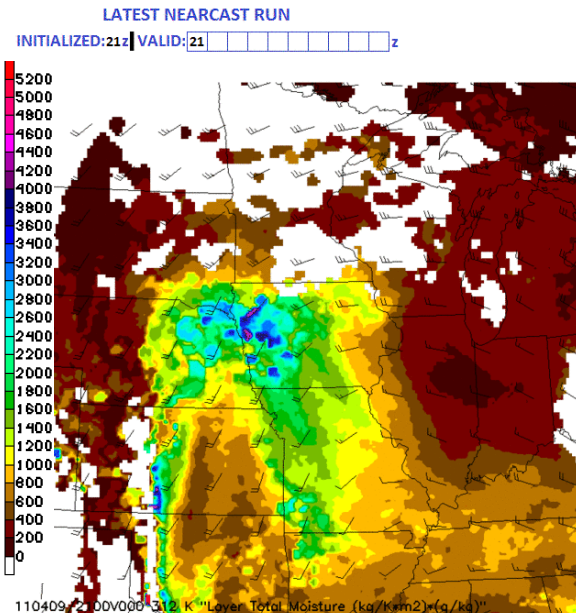
21z Isentropic Nearcasting Model Cycle

Total Moisture Availability Products for Heavy Precip.

Low (312K) Isentropic Level

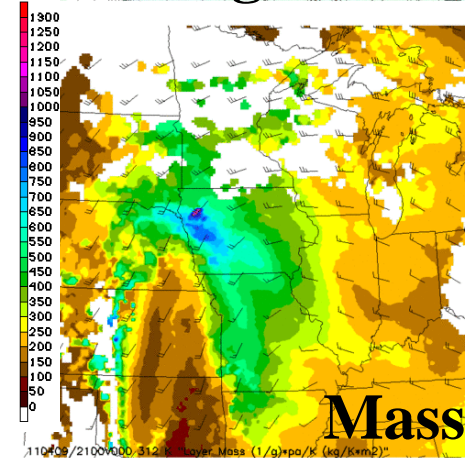


20110409-2100z NearCast - Valid: 20110409-2100z



$\frac{1}{g} \frac{\partial P}{\partial \theta}$: Mass in Isentropic Layer
(Pa/K)

$\frac{1}{g} \frac{\partial P}{\partial \theta} q_{av}$: Total Moisture in
Isentropic Layer
(Pa/K)*MR



- *Movement of highest total moisture was toward area of heavy precipitation was reconfirmed by each successive run*
- *Highest levels of total moisture became better collocated with instability after 00z*

Summary of Event

What isentropic model told us

What Happened

NW Iowa: 21z-00z

- Max in convective instability moving into previously stable region
- Strong destabilization tendencies
- Winds veering with height
- Strong ascent
- Low total moisture and weak TMFC



- Severe convection
- Short-lived, small-scale
- Only weak, local precip

SE Minnesota into Wisconsin: 02z-...z

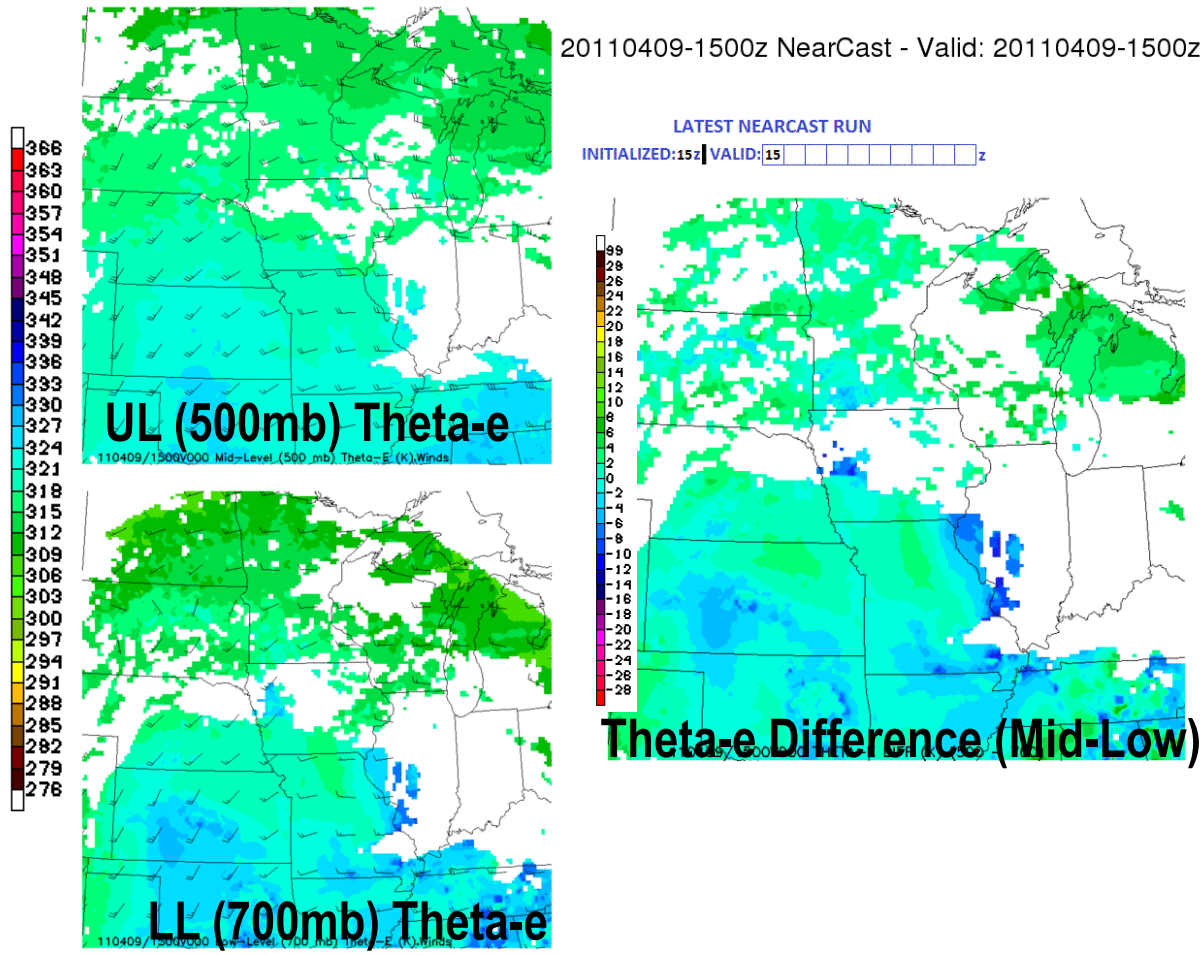
- Max in convective instability moving into previously weakly unstable region
- Weaker destabilization tendencies
- Less veering of winds with height
- Strong to moderate ascent
- High total moisture and strong TMFC



- Non-severe but strong convection
- Long-lived, large-scale
- Heavy and widespread precip.

Conversion Back to Pressure Coordinates

- To ease user acceptance, the isentropic outputs can be interpolated to the more familiar pressure coordinates for initial display, though some information may be lost.



- New derived isentropic products can be displayed in this format as well.

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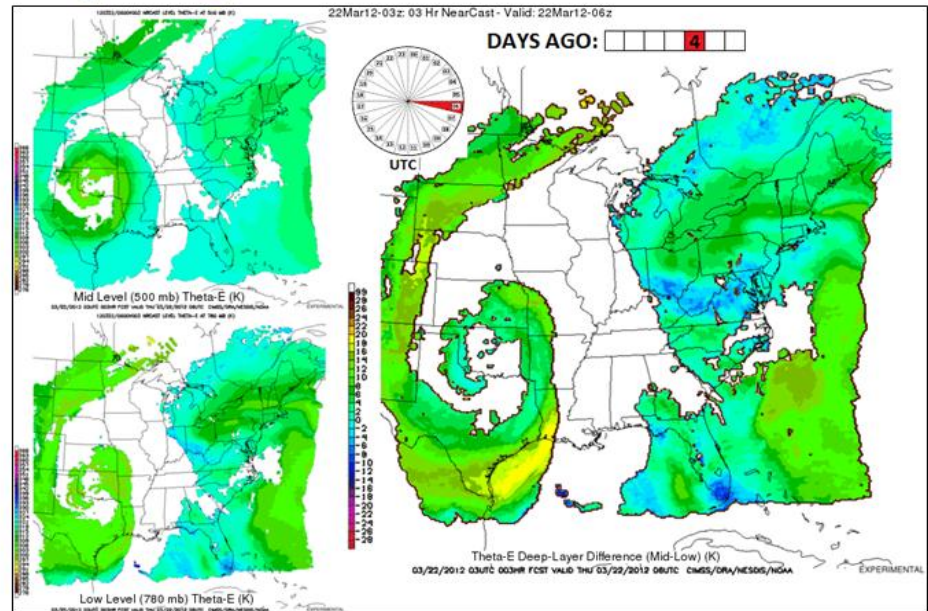
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What Next?

NearCast Model has been modified to run anywhere on the globe

- Uses NCEP GFS data for Heights and initial Winds
- Uses EUMETSAT SEVIRI data as GOES-R surrogate
 - Evaluation at ESSL planned for this summer
- Bias removal underway over US

Exposing Forecasts to satellite NearCasts



6 day NearCast Loop

NearCasts are updated hourly and available within minutes of observations

Continued Testing and Evaluation

- More Proving Ground activities
 - Adding NCEP/OPC to SPC and AWC
- Need to provide materials to WFOs for introducing more forecasters to NearCasts
 - E.g., daily exposure to loops of current events could help

